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CHALLENGES OF STUDENTS IN STEM: A CLOSER LOOK AT HOW FEMALE ENGINEERING STUDENT EXPERIENCES VARY COMPARED TO THOSE OF OTHER STEM STUDENTS

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Abstract

Despite recent concentrated efforts to attract young women to STEM, female engineers remain particularly underrepresented compared to women in other scientific fields. Thus, this study aims to gain insight into STEM student experiences while comparing challenges/experiences of women in engineering (WE) to male engineers (ME) or women majoring in other sciences (WS).

An IRB approved, 31-question survey was completed by engineering and science students. The study assessed student demographics, challenges faced within their discipline, desired support from the University, feelings of representation, and perceived incidence of institutional barriers.

In total, 82 students (Engineering 46.4%; Sciences 47.6%;) completed the survey. The most common challenges to STEM students included time management (71%) and difficult curriculum (62%). Half of the students reported a need for modified/improved teaching methods. STEM students reported receiving support from family (74.4%) and fellow university students (62.8%). However, 37.2% of respondents reported not having any sort of mentor in their field of study as they navigate their college careers.

The most notable differences between subgroups occur (1) between women and men in engineering, and (2) between women in engineering and other STEM disciplines. In addition to support from family/friends, the female engineers indicated more reliance on professors as a key support system compared to other subgroups (73% WE; 48% WS; 41% ME). Additionally, 60% of WE reported personally experiencing institutional/cultural barriers related to their program of study compared to only 14% of ME, and 28% of WS.

Results of this study suggest that women in engineering still experience different challenges than male colleagues or women in adjacent STEM fields. Support efforts aimed at mentorship by faculty and established outside mentorship may lead to increased student satisfaction and improved retention rates for students across STEM disciplines.

Introduction

Despite a 66.3% increase in the numbers of women earning STEM degrees between 2009 and 2018 [1], still only a third of STEM degrees conferred are to women [2]. Though some attribute the root of the imbalance to a lack of young women's enrollment in STEM another major contributor is poor retention rates. In fact, greater dropout rates of women compared to men at all levels of STEM education are so prevalent the phenomenon has been termed the "leaky pipeline" [3] suggesting the STEM environment is still less conducive to women's persistence in STEM education.

Factors identified as barriers for women and underrepresented populations' success in STEM include feeling excluded in male dominated environments [4], facing stereotypes or discrimination [5], lacking the ability to apply course material in real world scenarios[6], and lacking a sense of belonging [7]. Recent initiatives in the United States have focused on attracting and retaining women in STEM and identified best practices for combating the above challenges. Specifically, efforts proven to enhance female persistence in college include established learning communities fostering strong peer groups, availability of female faculty or mentors and the availability of tutoring in non-threatening environments [8]. Yet, even now women are 19% more likely than men to switch from a STEM to a non-STEM major [9].

Although it is true that many studies have accurately identified specific challenges of young women in STEM, the need exists to further assess experiences of young women in STEM subdisciplines. NSF reports the number of women having earned at least a bachelor's degree is uneven among disciplines accounting for 48% of life scientists, but only 16% of engineers [2]. In an effort to provide a university environment in which women engineers feel a sense of belonging, the need exists to highlight specific experiences and needs of women in engineering compared to those in the broader STEM disciplines. Our university provides a unique opportunity to contrast such experiences in that engineering and sciences are housed within one college. Thus, the focus of this survey was twofold, 1) to understand the experiences, motivation, support systems and challenges of women engineering students, and 2) to compare the women engineer's experiences to those of their male counterparts and women enrolled in science.

Results of this study can help engineering programs to understand not only the support systems necessary for women in STEM, but also the additional considerations necessary to foster greater retention and success for women engineers.

Methods

Participant recruitment for the IRB approved 31-question survey was conducted via e-mail during the Fall 2019 semester. The email was sent exclusively to students at our University in the College of Engineering and Science. Responses from 82 students were collected and analyzed as part of this study. In addition to demographic data, the survey assessed challenges faced within the student's respective discipline, desired support from the University, feelings of representation, and perceived incidence of institutional barriers for students in STEM fields. Data was first evaluated to understand overall trends with respect to students across all STEM disciplines. Further analysis was completed to compare trends between female engineering students, male engineering students, and female science students.

Results

Experiences of students in STEM fields. In total, 82 students completed the survey. Despite the small number of respondents, the data provided insight into the main challenges faced by students pursuing degrees in STEM fields. 46.4% of the students who participated in the study were pursuing engineering majors (Robotics & Mechatronics, Mechanical, Electrical & Computer, or Civil), 47.6% of respondents were majoring in other sciences (including

Chemistry, Biochemistry, Biology, Computer Science, Mathematics and Nursing). There was a fairly even distribution of students in their freshman, sophomore, junior, and senior years, but a lesser number of graduate student participation (8.5%). Figures 1 and 2 show the demographic breakdown and the current majors (respectively) of the students who participated in the survey.

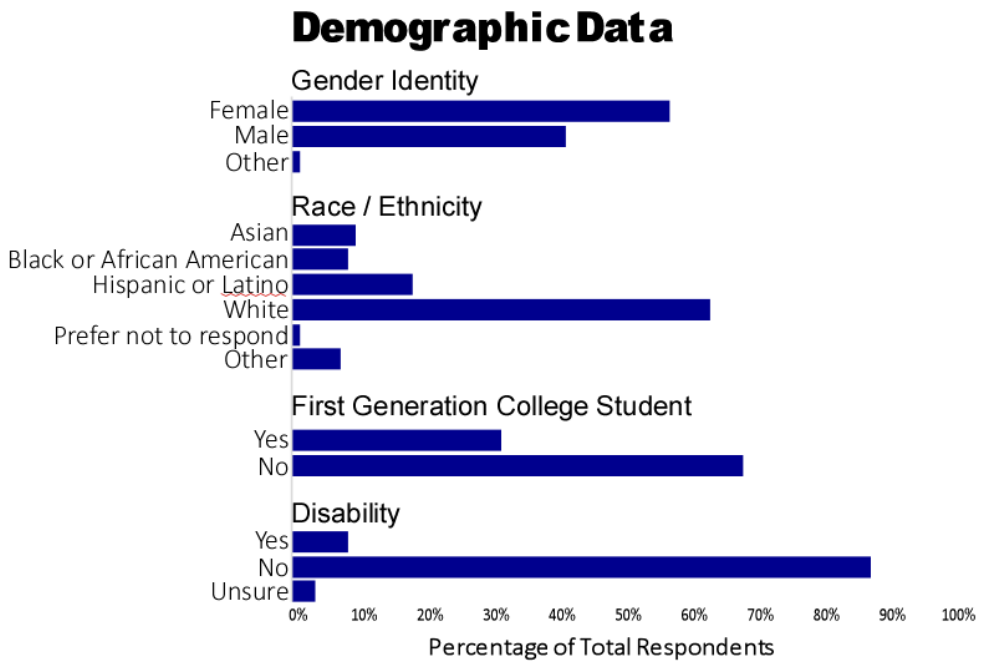

Figure 1. Demographic data from the 82 student respondents

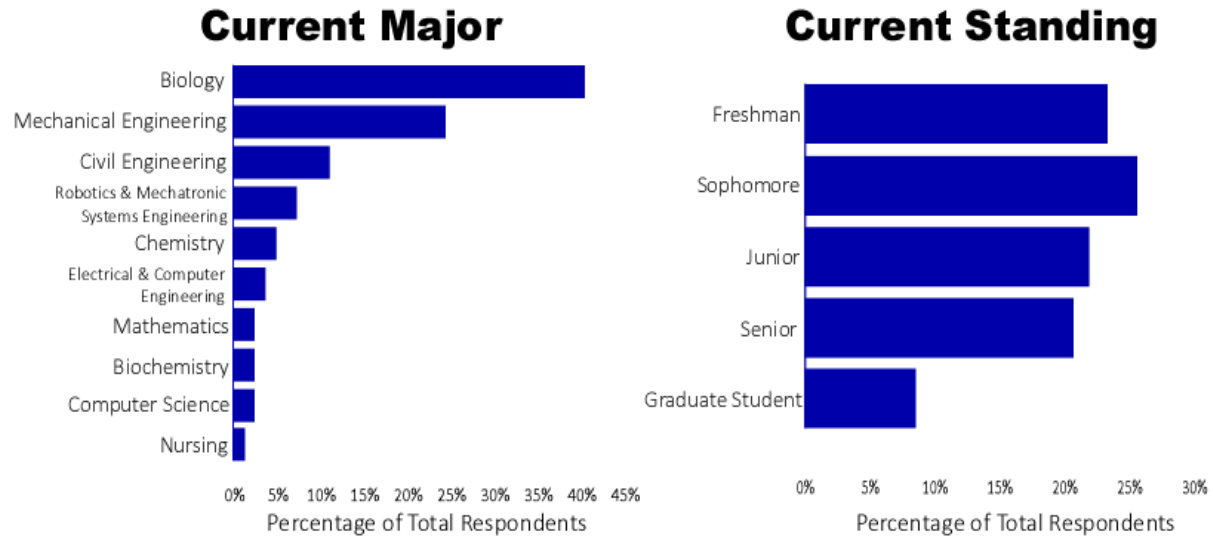

Figure 2. Current majors and standing of the students who completed the survey

The top challenges faced by students in STEM fields were time management (70.7%) and difficulty of the material (62.2%). Other challenges reported by students include a lack of

motivation (43.9%), not knowing how to study (29.3%), problems communicating with professors (28.1%), difficulty connecting with other students (18.3%), medical-related issues (17.1%), and a loss of interest in their program of study (14.6%). Figure 3 shows a breakdown of these challenges faced by students in STEM fields.

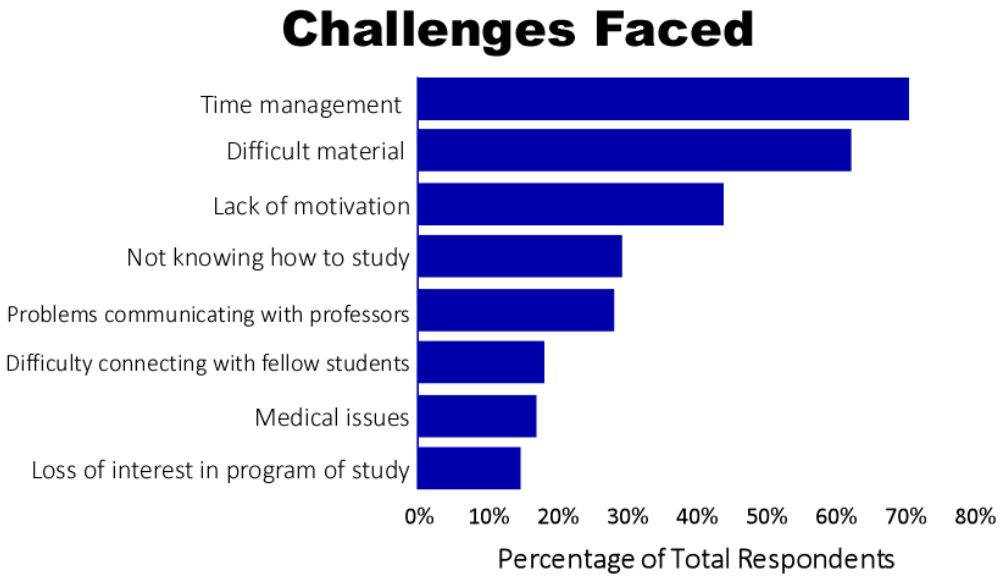

Figure 3. Challenges faced by students in STEM fields

The survey also evaluated what types of support that students feel they need from their university in order to remain and thrive in their respective field. Approximately half of respondents (51.3%) reported the need for modified teaching methods. Other sources of support students claimed to need from their university include mental health/stress management support (42.3%), mentor programs with grad students or staff (38.5%) and industry professionals (35.9%), networking opportunities within their program (32.1%), and tutoring support (32.1%). A comprehensive list of the support systems that students in STEM feel would contribute to their success is shown in Figure 4.

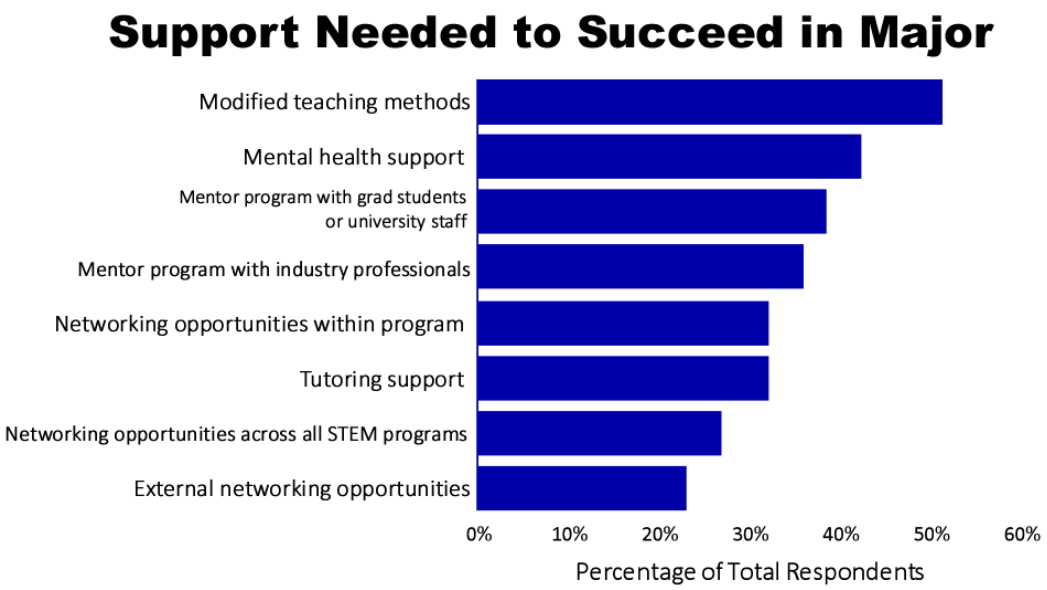

Figure 4. Types of support students need to succeed in their field of study

The survey also assessed the support systems that students currently rely on as they navigate their college careers. The primary support systems for students in STEM fields are family (74.4%), fellow university students (62.8%), friends (55.1%), and professors (50.0%). A detailed breakdown of the support systems students rely on for success is illustrated in Figure 5.

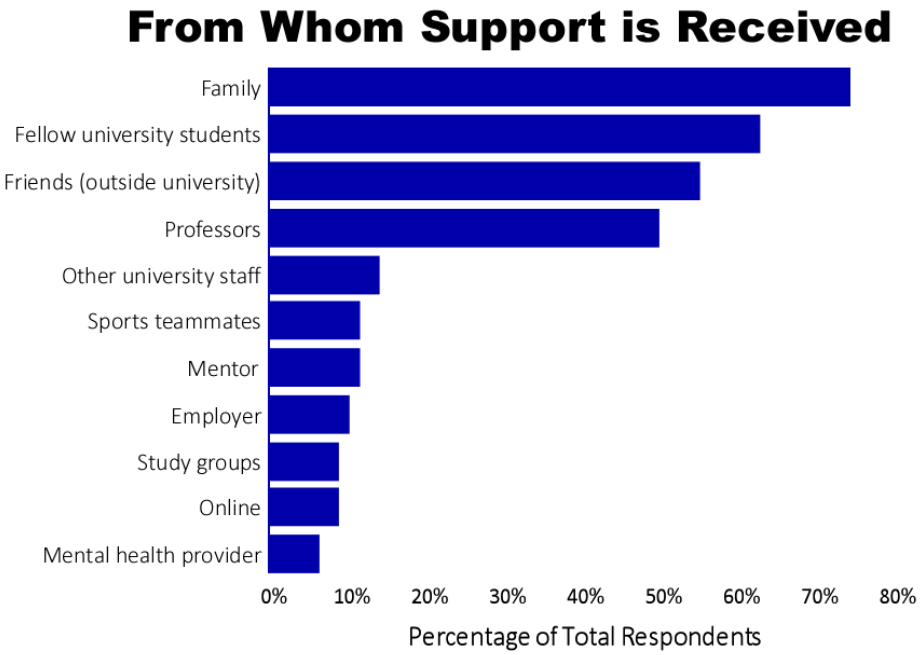

Figure 5. Support systems that students currently rely on for success in their field

Despite students' overall acknowledgement of the benefits of mentorship, 37.2% of student respondents still claim that they do not have a mentor in their field of study. Most students

(>80%) acknowledge that mentors would provide invaluable advice on the navigation of college classes and the selection of a career path. Over half of respondents claim that a mentor would also provide them with additional networking opportunities, support them in their goal-setting efforts, improve their overall confidence level, and support them emotionally as they pursue their degree. Figure 6 summarizes the students' perspectives on the benefits of mentorship, as well as how many of the students claim to benefit from such a relationship.

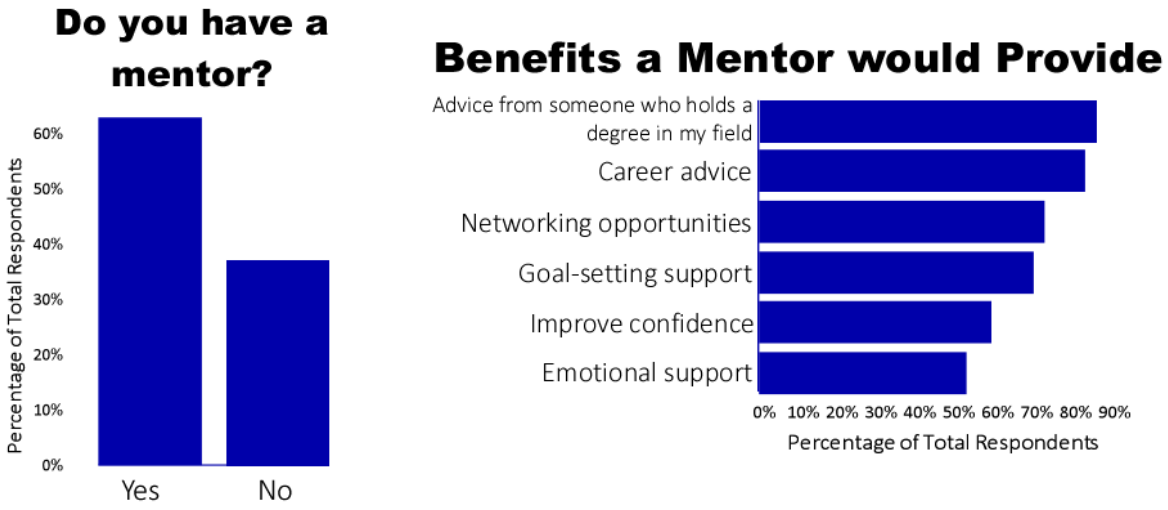

Figure 6. Student respondents' perspectives on mentorship

Comparison of Women in Engineering to Other Subgroups. Survey results were analyzed further to investigate the differences between the experiences of women pursuing an engineering degree (WE) to men pursuing an engineering degree (ME) and women pursing a degree in the sciences (WS).

When asked to indicate the various reasons why students chose their respective major, it was determined that women were generally more concerned with their positive impact on society (53.3% WE; 50.0% WS; 22.7% ME) while men were much more concerned with earning potential (40.0% WE; 44.4% WS; 77.3% ME). Many more WS reported having chosen their major as the fulfillment of a lifelong goal or dream compared to both males and females in engineering (13.3% WE; 56.3% WS, 27.3% ME). A list of the top reasons for having chosen one's major, subdivided into the responses of WE, ME, and WS, is shown in Figure 7.

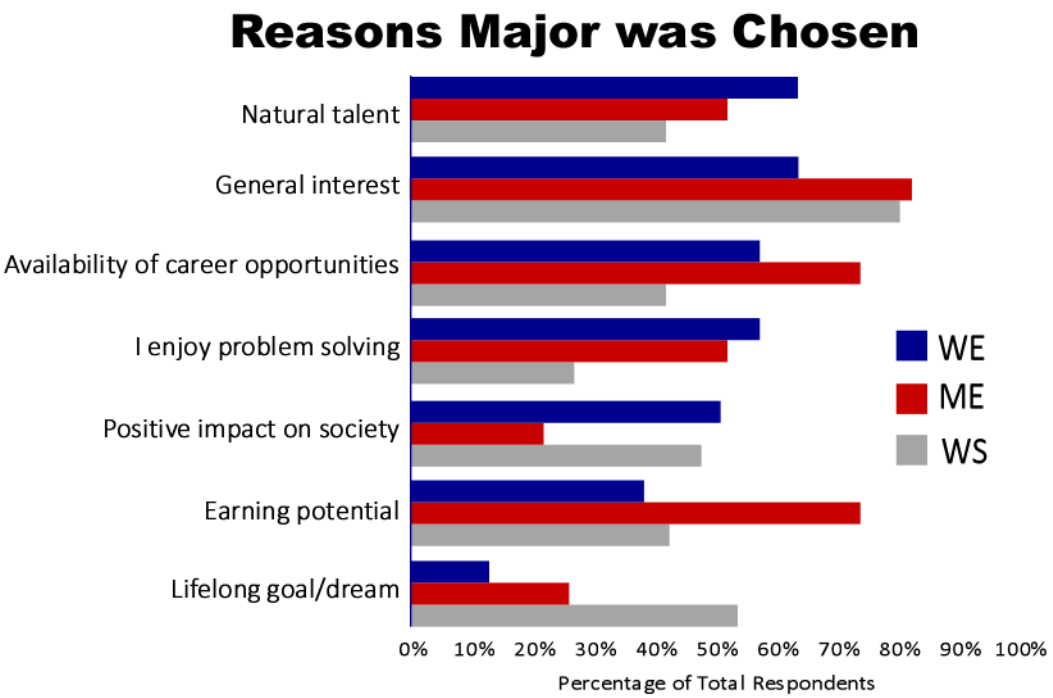

Figure 7. Reasons why WE, WS, and ME chose their respective major.

When analyzing responses from WE, WS, and ME regarding current and needed support systems, it was noted that WS reported a greater need for mental health/stress management support (40.0% WE; 55.2% WS; 36.4% ME) and networking opportunities within their program (20.0% WE; 44.8% WS; 27.3% ME) than men and women in engineering. Tutoring support was reported as a greater need for WS and WE than it was for ME (40.0% WE; 37.9% WS; 22.7% ME). The female engineers indicated more reliance on professors as a key support system compared to other subgroups (73.3% WE; 48.3% WS; 40.9% ME). Figure 8 summarizes the main support systems that WE, ME, and WS report needing to succeed in their field and currently rely on for success.

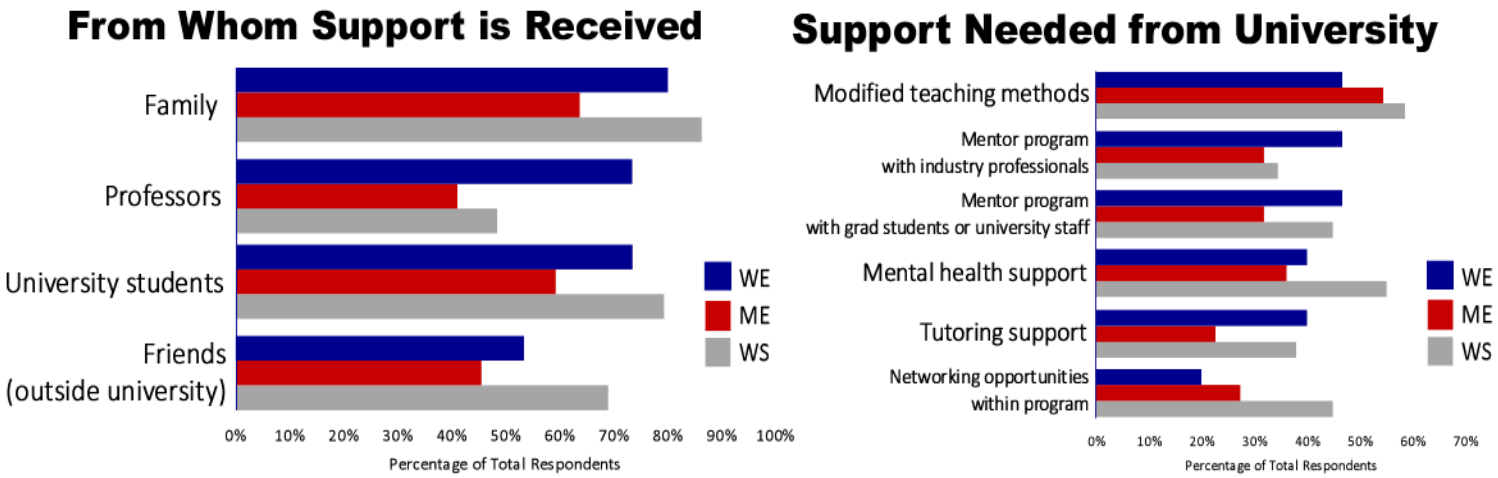

Figure 8. Current sources of support and needed support systems for WE, ME, and WS

Approximately the same percentage of WE and WS reported not feeling represented in their field of study. Despite this statistic, 60% of WE reported personally experiencing institutional/cultural barriers related to their program of study compared to only 14% of ME and 28% of WS.

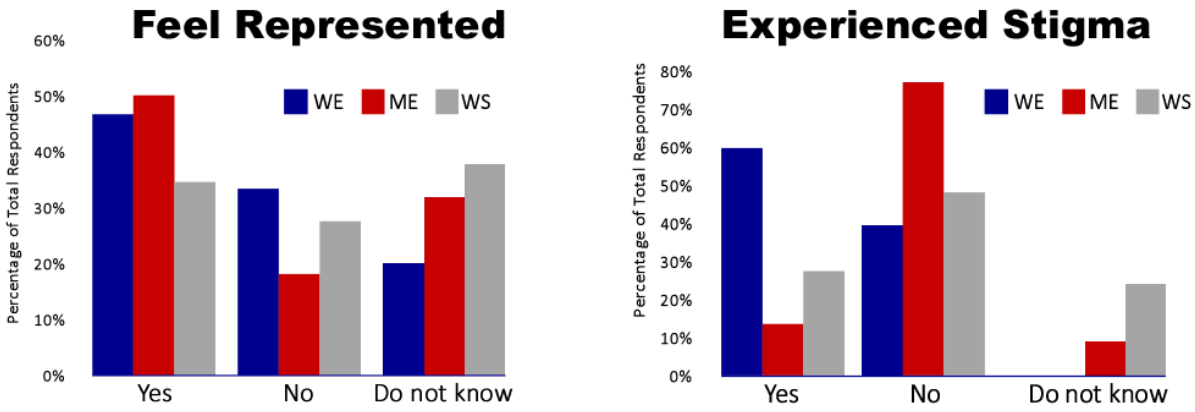

Figure 9. The percentage of WE, WS, and ME who report feeling represented and experiencing stigma in their field of study

Discussion

Underrepresentation of women enrolled in engineering majors is widely recognized. While many studies have assessed the challenges of women in STEM as whole, fewer have evaluated the specific experiences of women in engineering. Thus, the purpose of this study was to survey women in engineering to investigate how their challenges, support systems and feelings of representation compare to women in other STEM disciplines or their male counterparts.

Paths Into STEM. Recognition of the differing factors driving women and men into STEM careers can help develop academic environments and programs that naturally increase recruitment and retention of women in STEM fields. Survey results reveal that WE are equally driven to choose their respective major by a natural aptitude for learning, a general interest in their field of study, availability of career opportunities after graduation, and a love for problem solving. WS are more motivated to pursue the sciences due to interest in their field and the opportunity to fulfill a lifelong goal while ME are more likely than both WE and WS to select their major based on earning potential. The fact that women report higher concern with selecting a career that allows them to focus their positive impact on society correlates with trends surrounding female enrollment in engineering. Consistently, the highest female enrollment in engineering is within the Environmental or Biomedical Engineering disciplines [10], two career paths which provide opportunities to serve people and the community. A greater emphasis in STEM courses should be placed on sociotechnical thinking and civic engagement so that students can better understand how their technical learning influences the greater social context.

Survey Timing. The survey questions were sent and the answers were collected in Fall 2019. Therefore, the results presented in this paper do not address the specific challenges due to the COVID pandemic. However, some of the outcomes of disruptive effects of COVID-19 in higher education were seen in the student answers even before the pandemic, mainly in the area of mental health and the need for strong support systems. When analyzing responses from WE, WS, and ME regarding current and needed support systems, it was noted that WS reported a greater need for mental health/stress management support (40.0% WE; 55.2% WS; 36.4% ME) than men and WE. This could be attributed to the fact that many undergraduate science majors in our institution are planning to apply to professional schools with competitive admissions requirements post-graduation, whereas many of our engineering students prefer working for a few years before applying to graduate schools. Research has shown that time-management practices can affect scholarly achievement [11]. In addition to providing mental health support, learning and practicing time-management strategies to improve time-management skills is critical in reducing student anxiety and stress.

Support Systems in STEM. Student responses indicate that one of their biggest sources of support comes from family, followed by fellow university students and then outside university friends. Female engineers indicated more reliance on professors as a key support system compared to other subgroups (73.3% WE; 48.3% WS; 40.9% ME) while WS relied more on family, classmates, and friends than professors. In general, the ME reported lower percentage in all support sources indicating less reliance on support systems.

Interestingly, WE are more likely than WS and ME to turn to professors for support. Considering all survey respondents attend the same university, it is possible that this statistic is influenced by the university's smaller size and subsequent lack of graduate student instructors or teaching assistants. However, it should be noted that WE are generally willing to seek help from professors. Perhaps smaller class sizes are an effective way to provide this support and foster this connection between students and professors. WE were also most likely to suggest the need for expanded mentor programs. Placing an emphasis on the growth and advancement of mentor programs within universities would likely help support and retain WE as they navigate their college careers.

Another needed area of university support identified in the survey was the option to have modified teaching methods. Flexible teaching and modified delivery methods were specifically noted in over half (51.3%) of responses for students to succeed in their respective field. Flipped teaching and modified learning have shown to be effective in increasing student preparation and performance of college students [12] [13]. Although many STEM courses were incorporating team-based teaching, project-based experiences, or inquiry-based learning, undergraduate lectures were rarely recorded when the survey was taken. However, at the beginning of the COVID pandemic, STEM courses moved to online delivery and lectures were captured in real time and made available to students to watch as needed. Whether STEM courses are delivered in-person or remote, survey results showed the need to not only integrate new teaching methodologies, but also modified delivery methods that allow for flexible student learning.

Sense of Belonging. Self-Determination Theory proposes that a sense of belonging is a primary factor motivating a student's likeliness to engage and succeed in education [14]. In this study, aspects of belonging were measured as the students' feelings of representation and experiences of stigma within his or her field of study. Approximately 50% of both WE and ME students reported feeling represented in their field of study which was higher than the 35% of WS. One interesting finding is greater than 30% of ME and WS report not knowing if they feel represented, perhaps signaling such students haven't considered feelings of belonging in the past due to their relatively higher representation within their field (compared to WE) [2]. Similarly, despite comparable feelings of representation, a much larger percentage of WE reported experiencing institutional/cultural barriers or stigma within the field of study.

Comparing the present data to that of a prior study provides insights into women's sense of belonging in school versus the workplace [15]. Although each study has a relatively low sample size, women engineers in the workplace reported comparable feelings of representation and experiences of stigma as reported by the female engineering students. However, compared to female science students, fewer female science professionals report feeling represented accompanied by a higher incidence of feeling stigma in the field. Results may be indicative of female enrollment in the science majors recently becoming more balanced than the number of women working in STEM professions.

Conclusion

The results of this survey provide insight into best practices academia can implement to support students in STEM. Compared to many studies evaluating the experiences of women in STEM, this survey data provides insights into the challenges of female engineering students and the resources necessary for their success. Data was collected in a university setting where both engineering and science majors are enrolled within the same college allowing for a normalized college environment. Compared to many studies evaluating the experiences of women in STEM, this survey data provides insights into the particular challenges of female engineering students and the resources necessary for their success.

The authors recognize women from underrepresented minority groups may experience additional challenges while pursuing STEM degrees and careers [16]. Future research by this team will focus on further demographic assessment of the responses. The process will include a similar survey with recruitment specifically targeted at underrepresented women in STEM programs to identify any additional challenges they may face. Finally, since this survey was completed pre-COVID, future assessment will be conducted to determine and compare the change between engineering and science students' challenges and needs during and post-pandemic.

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